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Thermal Recovery of NIF Amplifiers

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Abstract

The issue of thermal recovery of the NIF amplifiers has taken on increased emphasis as program goals move toward increasing the shot rate to once every four hours. This paper addresses the technical issues associated with achieving thermal recovery in the NIF amplifiers.

Identifying thermal recovery needs requires development of a suitable set of recovery criteria that can be readily translated to the specification of necessary cooling hardware. In this paper we identify two temperature related thermal recovery quantities: (1) the difference between the average slab temperature and the temperature of other surfaces in the amplifier cavity, and (2) the temperature difference in the slab over the aperture. The first quantity relates to optical disturbances in the gas columns in the system, while the second quantity is associated with optical aberrations in the laser media itself. Several approaches for meeting the NIF recovery requirements are addressed. These include active cooling of the flashlamps and slab edge cladding, as well as changing the amplifier and beamtube fill gas.

Approaches for using flashlamp cooling to accelerate thermal recovery of the slab are addressed. It is shown that slight adjustments in the cooling gas temperature (less than 1 degree C) can translate to reductions in thermal recovery time of more than a factor of two, or significant reductions in the required gas flow rate.

Edge cladding cooling is discussed as a means to reduce optical distortions in the slabs. We develop a NIF baseline design requirement based on theoretical and numerical predictions. The numerical calculations include detailed three-dimensional simulations of the temperature and stress state in the laser slab during the thermal recovery cycle, and calculation of the optical consequences of these thermal and mechanical conditions. In the optical portion of the calculation, the effects of temperature, stress, and thermal expansion on the optical path length are included. These calculations show that only partial compensation of thermal expansion is afforded by the negative dn/dT of the laser glass, and that edge cladding cooling can reduce the optical distortions by over a factor of four. This is shown to be necessary for a 4 hour shot period. One candidate edge cladding cooling design is discussed

Finally, the impact of gas fill selection is addressed, focusing on the differences between nitrogen and helium fills, Optical disturbances in the gas columns are related to the Gladstone-Dale constant for the gas and the maximum difference between surface temperatures in the system. Because the Gladstone-Dale constant of helium is a factor of 8 lower than that of nitrogen, system thermal equilibration requirements can be relaxed by a factor of 8 when helium is used as the amplifier and beamtube fill gas. Thus, a static helium filled system will have a substantially lower sensitivity to surface temperature differences in the system than will a nitrogen filled system, thereby substantially reducing system requirements for cooling uniformity.

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